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Anisotropic permeability and fluid dispersion in pervasively fractured lavas, Rotokawa Geothermal System, New Zealand.

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Geothermal provides nearly 20% of New Zealand's electricity as well as increasing opportunities for direct use. In New Zealand's ~20 high temperature geothermal systems, fluids flow dominantly through fractured rocks with low matrix permeability. It is important to understand the nature of these fracture systems, and how fluids flow through them, so that the geothermal systems may be more efficiently and sustainably used. Here we present fluid flow calculations in several distinct discrete fracture models, each of which is broadly consistent with the fracture density and high dip magnitude angle distributions directly observed in borehole image logs at the Rotokawa Geothermal Field (>300°C, 175 MWe installed capacity). This reservoir is hosted in fractured andesites. In general, fractures are steeply dipping, and the reservoir is known to be compartmentalized.

Our new code describes fluid flow through large numbers (e.g., thousands) of stochastic fracture networks to provide statistical distributions of permeability, permeability anisotropy and fluid dispersion at reservoir scale (e.g., 1 km^2). Calculations can be based on both the cubic flow law for smooth-walled fractures and the Forchheimer flow model, which includes an additional term to describe the nonlinear drag (i.e. friction) in real fractures caused by surface roughness of the fracture walls.

Models with fracture density consistent with borehole observations show pervasive connectivity at reservoir scales, with fluid flow (hence permeability) and tracer transport predominantly along the mean fracture orientation. As the fracture density is varied, we find a linear relationship between permeability which holds above a well-defined percolation threshold. Permeability anisotropy is in general high (~10 to 15), because of the steeply dipping fractures. As fracture density decreases, mean anisotropy decreases while its variability increases. Significant dispersion of fluid occurs as it is transported through the reservoir. These fracture models will inform more traditional continuum models of fractured geothermal reservoirs hosted in volcanic rocks, to provide a better description of fluid flow within reservoirs and aid the responsible and sustainable use of that resource in the future.